PHYSIOLOGY EXAMINATION
Unit Exam #1
October 5, 1998
8:30-10:30AM

Directions: Select the one best answer and fill in the space below the corresponding letter on the answer sheet.

Cellular Physiology Questions [#1-8 Banks #9-24 Heiny]

Use the following letters when answering questions 1-2

A) Plasma space
B) Interstitial fluid space
C) Extracellular fluid space
D) Intracellular fluid space
E) Total body water space

1. Each one of these spaces could be measured with a single tracer:

   A) A, B, and E  
   B) A, C, and E  
   C) B, C, and D  
   D) C, D, and E  
   E) A, B, C, D, and E

2. Which one of the following statements regarding the size of these spaces is correct?

   A) A, B, C, and D increase during infusion of a hypertonic sodium chloride solution  
   B) A and B increase if the plasma colloid osmotic pressure decreases  
   C) C increases but D decreases during infusion of a hypertonic sodium chloride solution  
   D) C decreases but D remains the same during prolonged (one to two hours) sweating  
   E) Ingestion of water increases A, B, C, but not D

3. Which one of the following pairs of values represents the approximate total amount of potassium and glucose in the extracellular fluid space of a 70-kg man? There is approximately

   A) 60 Eq of K⁺ and 14 gm of glucose  
   B) 5 mEq% of K⁺ and 100 mg% of glucose  
   C) 5 mEq/l of K⁺ and 100 mg of glucose  
   D) 60 mEq of K⁺ and 14 gm of glucose  
   E) 6 Eq of K⁺ and 100 gm of glucose
Use the following thistle tube design with different solutes and membranes to answer this question.

![Thistle tube design](image)

<table>
<thead>
<tr>
<th>Solute</th>
<th>Membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td>i Calcium chloride (50 mM)</td>
<td>Rbc membrane</td>
</tr>
<tr>
<td>ii Potassium chloride (100 mM) + Urea (300 mM)</td>
<td>Rbc membrane</td>
</tr>
<tr>
<td>iii Albumin (8 g%) + Calcium chloride (100 mM)</td>
<td>Rbc membrane</td>
</tr>
<tr>
<td>iv Glucose (200 mM)</td>
<td>Skeletal muscle capillary unit</td>
</tr>
<tr>
<td>v Albumin (8 g%) + Calcium chloride (100 mM)</td>
<td>Skeletal muscle capillary unit</td>
</tr>
</tbody>
</table>

4. Which one of the following combinations of solutes and membranes results in the proper sequence of osmotic pressures (i.e., the pressure applied to the plunger in order to prevent water movement into the cylinder) is correct?
   
   A. i > ii > iii  
   B. ii > i > = v  
   C. iii > i > ii  
   D. iii > ii > i  
   E. v > ii > i

5. The following data were obtained with substance (X) in a healthy, 80 kg male:
   
   Amount of X injected = 15 mg  
   Steady-state plasma concentration of X = 0.003 mg/ml
   
   Assuming no excretion or metabolism of X during the experiment, which of the following is most likely to be substance X?
   
   A) Inulin  
   B) Evans Blue  
   C) Urea  
   D) Deuterium oxide (D₂O)  
   E) Mannitol

6. Red blood cells placed in a solution of 300 mM Urea and 75 mM NaCl would:
   
   A) Burst almost instantaneously.  
   B) Rapidly shrink to about one-half their volume in plasma.  
   C) Rapidly swell to about twice their volume in plasma.  
   D) Be of similar size to those in 300 mM sucrose.  
   E) Rapidly take up NaCl.
7. Equal amounts (mass) of Evans Blue dye, inulin and urea in a small volume were injected intravenously into a 100 kg person. At the new steady state (assume no loss of any of the substances from the body during the experiment):

A) The concentration of Evans Blue in plasma would be the lowest concentration of the 3 substances.
B) The ratio of the plasma concentration of Evans Blue to inulin would be about 4/1.
C) A 20% decrease in vascular volume (a hemorrhage) would then result in an increase in the plasma concentration of Evans Blue during the following 30 min.
D) A 20% decrease in vascular volume (a hemorrhage) would then result in a decrease in the plasma concentration of urea during the following 30 min.
E) The plasma concentration of inulin and urea would be the same.

8. Which one of the following statements regarding the intracellular fluid space is correct?

A) The osmolar concentration of intracellular fluid increases during sweating
B) The volume of intracellular fluid space decreases during a hemorrhage
C) The volume of the intracellular fluid space increases as the plasma colloid osmotic pressure decreases
D) Approximately 20% of the body weight is normally present as water in this space.
E) The inulin concentration in this space would increase during sweating

Log values that may be useful for the following question

\[
\begin{align*}
\log \frac{130}{13} &= +1 \\
\log \frac{13}{130} &= -1 \\
\log \frac{130}{4} &= +1.51 \\
\log \frac{4}{130} &= -1.51 \\
\log \frac{140}{4} &= +1.54 \\
\end{align*}
\]

9. Consider a resting cell membrane that is permeable only to K\(^+\). If the intracellular K\(^+\) concentration decreases from 140 to 130 mM and the plasma K\(^+\) concentration stays constant at 4 mM, the RMP will

A) hyperpolarize by about 30 millivolts
B) hyperpolarize by a few millivolts
C) depolarize by a few millivolts
D) depolarize to the threshold potential for triggering an action potential
E) stay the same

10. At the RMP there is a net

A) low density of positive charges at the inner surface of the membrane
B) high density of positive charges at the inner surface of the membrane
C) low density of positive charges at the outer surface of the membrane
D) low density of negative charges at the outer surface of the membrane
E) large excess of positive charges in the bulk intracellular fluid

11. The defining feature(s) of all ion channel proteins is (are)

A) a central pore that can be opened or closed
B) an enzymatic domain that is activated by membrane potential
C) an inactivation domain that desensitizes the channel
D) an extracellular ligand-binding domain and an intracellular inactivation domain
E) a four-subunit structural motif
12. Cell A has a $P_{Na}/P_{K}$ ratio of 0.001 and cell B has a $P_{Na}/P_{K}$ ratio of 0.01. Both cells have the same intracellular and extracellular [K$^+$] concentration. The RMP of cell A will be

A) the same as the RMP of cell B
B) less negative (i.e. depolarized compared with the RMP of cell B)
C) more negative (i.e. hyperpolarized compared with the RMP of cell B)
D) closer to $E_{Na}$ than cell B
E) none of the above

13. During the rising phase of the nerve action potential, the membrane potential depolarizes because a small number of positively charged

A) $K^+$ ions move to the inner membrane surface through open, voltage-dependent $K^+$ channels
B) $Na^+$ ions move to the inner membrane surface through open, voltage-dependent $Na^+$ channels
C) $Na^+$ ions move to the outer membrane surface through open, voltage-dependent $Na^+$ channels
D) $K^+$ ions move to the outer membrane surface through resting $K^+$ channels
E) $Na^+$ ions move together with a small number of positively charged $K^+$ ions to the inner membrane surface through open, voltage-dependent $Na^+$ and $K^+$ channels

14. During the falling, repolarization phase of the nerve action potential the membrane is

A) equally permeable to chloride and potassium ions ($P_{Cl}/P_{K} = 1$)
B) more permeable to sodium than to chloride ions ($P_{Na}/P_{Cl} << 1$)
C) more permeable to sodium than to potassium ions ($P_{Na}/P_{K} >> 1$)
D) more permeable to potassium than to sodium ions ($P_{Na}/P_{K} << 1$)
E) equally permeable to potassium and sodium ions ($P_{Na}/P_{K} = 1$)

15. The functional refractory period (FRP) of a nerve membrane defines

A) the period during which a second action potential can be triggered if the initiating depolarization is larger than normal
B) the period during which a second action potential cannot be triggered even if the initiating depolarization is larger than normal
C) the period during which a second action potential can be triggered by any depolarization that exceeds threshold potential
D) the minimum period that must follow an AP before all of the $Na^+$ channels have moved to the inactive conformation
E) the shortest interval that must follow an AP before a second AP can be triggered in a nerve that is firing APs at its highest frequency

16. At the start of the repolarization phase of the nerve action potential, the driving force for $K^+$ ion movement is

A) outward because the membrane potential is more positive than $E_K$
B) outward because the membrane potential is more negative than $E_K$
C) zero because the membrane potential equals $E_K$
D) inward because the membrane potential is more positive than $E_K$
E) inward because the membrane potential is more negative than $E_K$
17. During electrotonic spread of depolarization along a membrane, positive charges move laterally along the

A) inner membrane surface and depolarize adjacent membrane regions to a larger amplitude than the initial depolarization
B) inner membrane surface and depolarize adjacent membrane regions to a smaller amplitude than the initial depolarization
C) inner membrane surface and depolarize adjacent membrane regions to the same amplitude as the initial depolarization
D) outer membrane surface and depolarize adjacent membrane regions to a smaller amplitude than the initial depolarization
E) outer membrane surface and depolarize adjacent membrane regions to the same amplitude as the initial depolarization

18. Active propagation of the nerve action potential is unidirectional because

A) $K^+$ and $Cl^-$ channels remain open after the AP and stabilize each membrane region at the RMP
B) $Ca^{2+}$ channels move to the inactive conformation after each membrane region has fired an AP
C) $Na^+$ channels move to the active conformation after each membrane region has fired an AP
D) $K^+$ channels move to an inactive conformation after each membrane region has fired an AP
E) $Na^+$ channels move to an inactive conformation after each membrane region has fired an AP

19. If the RMP of a nerve depolarizes from $-80$ to a new constant potential of $-70$ mV,

A) a larger fraction of $Na^+$ channels move to the closed state; the membrane is more excitable
B) a larger fraction of $Na^+$ channels move to the inactive state; the membrane is less excitable
C) some fraction of $Na^+$ channels move to the open state; the membrane is more excitable
D) there is no change in the distribution of $Na^+$ channels among closed, open and inactive states
E) the number of $Na^+$ channels increases rapidly and the membrane becomes arrhythmical

20. In demyelinating disease, conduction is impaired because

A) the space constant of the internode is decreased
B) $Na^+$ channels in the node are inactivated
C) active propagation along the internode is slowed
D) the space constant of the nodal membrane is decreased
E) none of the above

21. The normal anatomical sequence of electrical excitation of the heart is

A) spontaneous action potentials originate in the SA node, propagate through the atria, then to the AV node and AV bundle (bundle of His), next to the bundle branches and finally to the Purkinje fibers and myocardial cells of the ventricles
B) spontaneous action potentials originate in the SA node, propagate to the AV node, then to the atrium, next to the AV bundle (bundle of His) and bundle branches, and finally to the Purkinje fibers and myocardial cells of the ventricles
C) spontaneous action potentials originate in the AV node, propagate to the atria and SA node, then to the AV bundle (bundle of His), next to the bundle branches and finally to the Purkinje fibers and myocardial cells of the ventricles
D) spontaneous action potentials originate in the SA node, propagate to the Purkinje fibers and bundle branches of the atria, travel to the AV node and AV bundle (bundle of His), and finally to the myocardial cells of the ventricles
E) spontaneous action potentials originate in the AV node, propagate to the atria and SA node, then to the bundle branches, and finally to Purkinje fibers and myocardial cells of the ventricle
22. During Phase 0 of the ventricular action potential

A) $Na^+$ channels open, $Na^+$ ions move in and depolarize the membrane potential towards $E_{Na}$
B) $Na^+$ channels inactivate and transient outward $K^+$ channels open. $K^+$ ions move out partially to repolarize the membrane potential towards $E_K$.
C) Voltage-dependent $Ca^{2+}$ and $K^+$ channels open, $Ca^{2+}$ ions move in, $K^+$ ions move out and the membrane potential is intermediate between $E_{Ca}$ and $E_K$.
D) Voltage-dependent, delayed $K^+$ channels and resting $K^+$ channels are fully open, $K^+$ ions move out to repolarize the membrane towards $E_K$.
E) $Ca^{2+}$ channels inactivate, causing the membrane potential to repolarize towards $E_K$.

23. One form of the cardiac arrhythmia Long Q-T syndrome arises because

A) the primary pacemaker cells become damaged and other regions of the heart fire action potentials at an abnormal frequency
B) the Purkinje cells become damaged and propagating action potentials re-excite regions of the ventricle that would normally be refractory
C) a mutation in the voltage-dependent, delayed $K^+$ channel alters its function and it contributes less outward $K^+$ movement to repolarize the membrane potential
D) a mutation in the voltage-dependent $Na^+$ channels causes the $Na^+$ channel to inactivate more than normal, resulting in a small sustained influx of $Na^+$ during the action potential
E) all of the above

24. The pacemaker potential of SA node cells in the heart arises because a small net

A) inward movement of cations slowly depolarizes the membrane
B) outward movement of cations slowly depolarizes the membrane
C) inward movement of anions slowly depolarizes the membrane
D) outward movement of cations slowly hyperpolarizes the membrane
E) outward movement of cations repolarizes the membrane

Muscle Physiology Questions  [#25-44 Paul  #45-46 Quinlan]

Covalent modification of proteins by phosphorylation is a major mechanism for modulating muscle contractility. For questions 25-29, use the following proteins (lettered A-E) that, when phosphorylated, exert the stated action (answers may be used only once):

A. troponin I
B. myosin light chain
C. myosin light chain kinase
D. phospholamban
E. a plasmalemmal $Ca^{2+}$ -channel

25. Affects the duration of the cardiac action potential
26. Decreases the affinity for calmodulin
27. Activates smooth muscle contraction
28. Alters the binding of a protein to actin
29. Decreases the affinity of the $Ca^{2+}$ pump for calcium
30. The endothelial lining of blood vessels produces nitric oxide (NO) in response to changes in blood flow. NO activates G-kinase which leads to relaxation of the smooth muscle. A possible mechanism by which activation of G-kinase causes smooth muscle relaxation would be:

A. dissociation of troponin from tropomyosin
B. inhibition of myosin phosphatase
C. stimulation of IP\(_3\) production
D. increased thin-filament aggregation
E. none of the above

31. Fast glycolytic (FG)-fibers require the highest stimulation frequencies of all fiber types to achieve a fused tetanus. This is most likely attributable to the:

A. sparse amount of sarcoplasmic reticulum in FG compared to other fiber types
B. high glycolytic enzyme content in FG relative to other fiber types
C. faster intrinsic speed of these fibers attributable to its predominant myosin isoform
D. generally larger motor neurons associated with these fibers
E. lack of t-tubules in the FG-fibers

32. Compared with skeletal muscle in general, smooth muscle is characterized by slower contraction speeds and a lower rate of ATP utilization per unit force. This is most likely attributed to:

A. a lower cross-bridge cycling rate as indicated by a lower actomyosin ATPase activity in smooth muscle
B. the lack of a t-tubule system in smooth muscle
C. differences in the force-length relation between smooth and skeletal muscle
D. the smaller creatine phosphate concentration characteristic of smooth muscle
E. a contractile mechanism in smooth muscle based on folding of contractile filaments

33. Smooth muscle does not show the striations characteristic of skeletal muscle because:

A. smooth muscle cells are much smaller than skeletal muscle cells
B. smooth muscle does not possess a transverse tubule system
C. the arrangement of thick and thin filaments is not as ordered as in skeletal muscle
D. the fundamental contractile mechanism is different than that of skeletal muscle
E. smooth muscle, unlike skeletal muscle, in not a multinuclear cell

34. The so-called “Ca\(^{2+}\)-antagonists” are drugs that can inhibit Ca\(^{2+}\) entry across the sarcolemma. One might anticipate the effects of such drugs might include:

A. severe inhibition of skeletal muscle function
B. decreased vascular resistance
C. increased gastrointestinal motility
D. generalized increases in excitability of all muscle types
E. inhibition of action potential propagation

35. An afterload of \(\frac{1}{2}\) maximum isometric force is placed on a skeletal muscle (at resting length) and the muscle is maximally stimulated. The muscle lifts the load, shortens, then stops while maintaining this load at the shortened length. The shortening stops because:

A. Ca\(^{2+}\) release from the sarcoplasmic reticulum is enhanced at shorter lengths
B. at the shortened length, the load is isometric due to the force-length relation
C. passive force at the shortened length is increased
D. thick filament shortening is inhibited at the shortened length
E. none of the above
36. Blockade of inositol trisphosphate (IP$_3$) production in smooth muscle would most likely result in:

A. inability of the muscle to depolarize when stimulated  
B. failure to contract in response to depolarization  
C. increased rate of relaxation of the muscle  
D. inhibition of some receptor-mediated activation of smooth muscle contraction  
E. all of the above

37. With estrogen treatment, uterine smooth muscle expresses more of a myosin isoform with a high ATPase activity. One functional consequence of switching to an isoform with a faster crossbridge cycle would be:

A. a greater shortening velocity  
B. more t-tubule expression  
C. down regulation of troponin  
D. lower ATP utilization per force maintained  
E. more myosin generated from tropomyosin

38. You have developed a new compound that blocks the interaction between the dihydropyridine (DHP) receptor and the ryanodine receptor. After treatment with this compound, skeletal muscle:

A. would be unable to propagate an action potential along the sarcolemma  
B. would be unable to propagate an action potential down the t-tubule  
C. tropomyosin would no longer bind to troponin-T  
D. myosin ATPase purified from this muscle would be dramatically inhibited  
E. would no longer release Ca$^{2+}$ from the SR in response to an action potential

39. The steep increase in force with stretch that is seen at long muscle lengths is attributable to:

A. resistance due to compression of thin filaments  
B. mechanical properties of the passive elasticity inherent in muscle  
C. folding of thick filaments  
D. failure of glycolysis at large muscle lengths  
E. failure of activation at long muscle lengths

40. The relationship between shortening speed and afterload in muscle indicates that:

A. force generation increases with speed  
B. power output declines at both slow and fast shortening speeds  
C. contractile filaments shorten during contraction  
D. power output is constant for all shortening speeds  
E. the number of attached crossbridges increases with speed

41. An afterload equal to 50% of the isometric force would:

A. decrease shortening speed by a factor of 2 compared to the maximum shortening speed  
B. have little effect on muscle shortening speed  
C. increase shortening speed by a factor of 2  
D. decrease shortening speed by more than 2-fold  
E. enhance muscle activation

42. During a single crossbridge cycle:

A. myosin is cleaved from tropomyosin  
B. one ATP molecule is hydrolyzed  
C. two ATP molecules are hydrolyzed  
D. troponin-C binds to the ryanodine receptor  
E. thick filaments shorten by 10 nanometers
43. Relaxation of skeletal muscle is associated with:
   A. a rapid dissociation of thick filaments into myosin dimers
   B. uncoupling of the t-tubules from the surface membrane
   C. dissociation of calcium from troponin-C
   D. inhibition of creatine kinase
   E. formation of “rigor” links between actin and myosin

44. A type of genetic myopathy involves a defect in phosphorylase, the initial enzyme in the glycogenolytic pathway. What symptoms might be characteristic of this syndrome in skeletal muscle?
   A. lack of expression of ryanodine
   B. inexcitability due to failure of action potential propagation
   C. characteristic short sarcomere lengths
   D. low levels of muscle activity appear normal, but moderate levels of activity can not be sustained
   E. increases in shortening velocity for a given afterload compared to normal muscle

Use the following information to answer questions 45 and 46:

A 38 year old man undergoing surgery while anesthetized with halothane is noted to have a rising temperature (currently 101.4°F). He feels quite warm and he has diffuse muscle rigidity.

45. You suspect that the patient has a(n):
   A. Defect in hypothalamic thermoregulation.
   B. Occult infection.
   C. Defective calcium release channel (sarcoplasmic reticulum).
   D. Defect in glycogen metabolism.
   E. Impaired exercise tolerance.

46. Which drug would be most effective in treating this patient?
   A. Ryanodine receptor inhibitor (dantrolene).
   B. Sodium-potassium ATPase inhibitor (ouabain).
   C. Beta adrenergic blocker (propranolol).
   D. Beta adrenergic agonist (albuterol).
   E. L-type calcium channel blocker (verapamil).

Answers
1b 2c 3d 4d 5b 6c 7b 8a 9c 10c 11a 12c 13b 14d 15e 16a 17b 18e 19b 20a 21a 22a 23c 24a 25e 26c 27b 28a 29d 30e 31c 32a 33c 34b 35b 36d 37a 38e 39b 40b 41d 42b 43c 44d 45c 46a